Rec'd PCT/PTO 22 JUN 2001

U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE **TRANSMITTAL LETTER TO THE UNITED STATES**	ATTORNEY DOCKET NO. 7402/71290
DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 USC 371	U.S. APPLICATION NO. To Be Assigned 09/868994
INTERNATIONAL APPLICATION NO. PCT/JP99/07177	INTERNATIONAL FILING DATE PRIORITY DATE CLAIMED

JUN 22 2001

TITLE OF INVENTION
OPTICAL COMMUNICATION APPARATUS

APPLICANT(S) FOR DO/EO/US
Tomonari YOSHIMURA, Noritaka SAITO & Akimitsu OKITA

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ■ This is a **FIRST** submission of items concerning a filing under 35 USC 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 USC 371.
3. ■ This is an express request to begin national examination procedures (35 USC 371(f)).
4. ■ The US has been elected by the expiration of 19 months from the priority date (PCT Article 31).
5. ■ A copy of the International Application as filed (35 USC 371(c)(2))
   a. ■ is attached hereto (required only if not communicated by the International Bureau).
   b. ☐ has been communicated by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ■ An English language translation of the International Application as filed (35 USC 371(c)(2)).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 USC 371(c)(3))
   a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   b. ☐ have been communicated by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 USC 371(c)(3)).
9. ■ An oath or declaration of the inventor(s) (35 USC 371(c)(4)).
10. ■ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 USC 371(c)(5)).
11. Nucleotide and/or Amino Acid Sequence Submission
    a. ☐ Computer Readable Form (CRF)
    b. Specification Sequence Listing on:
       i. ☐ CD-ROM or CD-R (2 copies); or
       ii. ☐ Paper Copy
    c. ☐ Statement verifying identity of above copies

Items 12 to 19 below concern other document(s) or information included:

12. ■ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
    ■ Form PTO-1449
    ■ Copies of Listed Documents
13. ■ An assignment for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
14. ■ A FIRST preliminary amendment is attached.
    ☐ A SECOND or SUBSEQUENT preliminary amendment.
15. ☐ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ■ Application Data Sheet Under 37 CFR 1.76
18. ■ Return Receipt Postcard
19. ■ Other items or information: Search Report

JC18 Rec'd PCT/PTO 22 JUN 2001

U.S. APPLICATION NO. 09/868994 To Be Assigned	INTERNATIONAL APPLICATION NO. PCT/JP99/07177	ATTORNEY DOCKET NO. 7402/71290

	CALCULATIONS	PTO USE ONLY
20. ■ The following fees are submitted: **Basic National Fee (37 CFR 1.492(a)(1)-(5)):** Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO .... $1,000.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO .... $ 860.00 International preliminary examination fee (37 CFR 1.482) paid to USPTO, but international search fee (37 CFR 1.445(a)(2))paid to USPTO .... $ 710.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) .... $ 690.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1) to (4) .... $ 100.00		
ENTER APPROPRIATE BASIC FEE AMOUNT=	$ 860.00	
Surcharge of $130.00 for furnishing the National fee or oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date	$	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	CALCULATIONS	PTO USE ONLY
Total Claims	24 -20=	4	x $ 18.00	$ 72.00	
Independent Claims	2 - 3 =	0	x $ 80.00	$ 0.00	
■ Multiple Dependent Claim(s) (if applicable)			+$270.00	$	

	CALCULATIONS	PTO USE ONLY
TOTAL OF ABOVE CALCULATIONS=	$ 932.00	
☐ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.	$	
SUBTOTAL=	$	
Processing fee of **$130.00** for furnishing English Translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date.	$	
TOTAL NATIONAL FEE=	$ 932.00	
Fee for recording the enclosed assignment. The assignment must be accompanied by an appropriate cover sheet. **$40.00** per property +	$ 40.00	
TOTAL FEE ENCLOSED=	$ 972.00	
	Amount to be: refunded	$
	charged:	$

a. ■ A check in the amount of $972.00 to cover the above fee is enclosed.

b. ☐ Please charge Deposit Account No. 12-1216 in the amount of $ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ■ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 06-1135. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Kendrew H. Colton, Reg. No. 30,368
Fitch, Even, Tabin & Flannery
Suite 1600, South LaSalle Street
Chicago, Illinois 60603-3406
(202) 419-7000 (telephone)
(202) 419-7007 (facsimile)

Kendrew H. Colton

Kendrew H. Colton, Registration No. 30,368
One of the Attorneys for Applicant(s)

Date: June 22, 2001

09/868994
JC18 Rec'd PCT/PTO 22 JUN 2001

PATENT
Attorney Docket No. 7402/71290

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

YOSHIMURA et al.

Application No.: Not Yet Assigned

Filed: June 22, 2001

For: OPTICAL COMMUNICATION APPARATUS

June 22, 2001

PRELIMINARY AMENDMENT

Commissioner for Patents
Washington, D.C. 20231

Dear Sir:

Please amend this application ad follows:

<u>IN THE SPECIFICATION</u>:

At the top of the first page, just under the title, insert

☐ --This application is the National Phase of International Application PCT/JP99/07177, filed December 24, 1999 which designated the U.S. and that International Application

☐ was ☒ was not published under PCT Article 21(2) in English.--

Respectfully submitted,

FITCH, EVEN, TABIN & FLANNERY

By: Kendrew H. Colton

Kendrew H. Colton
Registration No. 30,368
Telephone No. (202) 419-7000
Facsimile No. (202) 419-7007

FITCH, EVEN, TABIN & FLANNERY
1801 K Street, NW
Suite 401L
Washington, DC 20006-1201
Telephone: (202) 419-7000
Facsimile: (202) 419 -7007

SPECIFICATION

OPTICAL COMMUNICATION APPARATUS

[TECHNICAL FIELD]

The present invention relates to a technique for optical communication using a plastic optical fiber, and particularly to an optical communication apparatus aiming to enhance heat resistance and perform long-distance communication.

[BACKGROUND TECHNIQUE]

Following recent increasing demands of optical communications using plastic optical fibers such as LAN, etc., increase in the communication distance and enhancement of resistance to environments, particularly resistance to heat (which means that the transmission characteristic is not varied with respect to the temperature variation) have been required.

A plastic optical fiber having a core made of methyl methacrylate polymer has been widely used as an optical transmission path for optical communications because it has advantages such as low absorbance, etc. A red light-emitting diode is generally used in an optical communication apparatus using such a plastic optical fiber as an optical transmission path.

In the conventional optical communication apparatus using a red light-emitting diode and a plastic optical fiber having a core made of polymethylmethacrylate resin as described above, the wavelength of light emitted from a light source is liable to vary due to temperature variation, and the variation of the wavelength of the emitted light sharply increases transmission loss of the plastic optical fiber. Particularly in the case of a light-emitting element having a broad full width at half maximum of wavelength, the wavelength components other than those around 650nm in wavelength are sharply attenuated. Therefore, the transmission loss is

increased and thus it is difficult to perform long-distance optical communication (transmission). For example, the transmission of about 100m at maximum can be performed by an optical communication apparatus using a plastic optical fiber which is currently on the market.

Recently, blue and green light-emitting diodes (LED) having high output power have been developed, and they have been expected to be used as light sources for optical communications. For example, JP(A)-8-116309 discloses that a blue light-emitting element is used as a light source for an optical communication apparatus from the viewpoint of the resistance to heat.

Since the optical communication apparatus disclosed in JP(A)-8-116309 uses the blue light-emitting element as a light source, the heat resistance of the light source itself is excellent. However, when this light source is used in combination with a plastic optical fiber, the heat resistance of the plastic optical fiber becomes lower.

That is, as disclosed in JP(A)-8-116309, the blue light-emitting element for emitting light having short wavelength has little effect on the light emission characteristic due to the temperature variation because it has a broad forbidden band width, and thus the heat resistance thereof is excellent. However, in the conventional plastic optical fiber, electron transition absorption due to thermal oxidation deterioration of the optical fiber more remarkably occurs to light having shorter wavelength, and thus the transmission loss is more greatly increased in the blue region.

Further, JP(A)-9-318853 discloses an optical transceiver for performing bi-directional communications through a single-core optical fiber, which uses a yellow light-emitting element for emitting light of 570nm in wavelength and a plastic optical fiber having a core formed of polymethylmethacrylate. However, this optical transceiver carries out the bi-directional communications through a single core, and thus it does not aim at long-distance transmission. Therefore, it has a drawback that S/N

is too low to carry out the long-distance optical transmission.

Still further, the optical communication apparatus disclosed in JP(A)-8-116309 and the optical transceiver disclosed in JP(A)-9-318853 are not suitable for long-distance transmission because the optical fibers used in these apparatuses are not suitable for optical transmission in a short-wavelength range such as blue, yellow, etc.

[SUMMARY OF THE INVENTION]

The present invention has been implemented in view of the problem of the conventional techniques as described above, and has an object to provide an optical communication apparatus using a plastic optical fiber which has excellent heat resistance and can perform long-distance transmission.

In order to attain the above object, according to the present invention, there is provided an optical communication apparatus, comprising:

an optical transmitter having a short-wavelength light-emitting element for emitting light signals corresponding to electrical signals input from the outside by using light emitted from the short-wavelength light-emitting element;

a plastic optical fiber having a core made of methacrylate polymer free from benzene rings, the amount of sulfur atoms that are not bound to the polymer in the core being set to 5ppm or less, one end of the optical fiber being optically coupled to the short-wavelength light-emitting element; and

an optical receiver having a photodetecting element coupled optically to the other end of the plastic optical fiber and adapted to generate an output electrical signal in accordance with the output of the photodetecting element.

In an aspect of the present invention, the amount of sulfur atoms that are not bound to the polymer in the core is set to 3ppm or less.

In an aspect of the present invention, the amount of sulfur atoms that are bound to the polymer in the core is set to a value in the range from 200 to 1000 ppm.

In an aspect of the present invention, the short-wavelength light-emitting element emits light having the maximum light emission wavelength of 600nm or less. In an aspect of the present invention, the short-wavelength light-emitting element is a yellow light-emitting diode for emitting light having the maximum light emission wavelength of 560 to 590nm or a green light-emitting diode for emitting light having the maximum light emission wavelength of 490 to 550nm.

Further, in order to attain the above object, according to the present invention, there is provided an optical communication apparatus, comprising:

an optical transmitter having a yellow light-emitting element for emitting light signals corresponding to electrical signals input from the outside by using light emitted from the yellow light-emitting element;

a plastic optical fiber having a core made of methacrylate polymer free from benzene rings, one end of said optical fiber being optically coupled to the yellow light-emitting element; and

an optical receiver having a photodetecting element coupled optically to the other end of the plastic optical fiber and adapted to generate an output electrical signal in accordance with the output of the photodetecting element, wherein the plastic optical fiber is designed so that light propagates in only one direction.

In an aspect of the present invention, the amount of sulfur atoms that are not bound to the methacrylate polymer in the core is set to 5ppm or less, preferably 3ppm or less.

In an aspect of the present invention, the yellow light-emitting element comprises a light emission diode which has the maximum light emission wavelength in the range from 560nm to 590nm, the full width at

half maximum of wavelength of 40nm or less and the total emission light amount of 0dBm or more, the plastic optical fiber has a transmission loss of 0.1dB/m or less at the wavelengths of 560 to 590nm, and the connection loss between the yellow light-emitting element and the plastic optical fiber is equal to 10dB or less, and the optical receiver has the minimum reception sensitivity of -25dBm or less at the wavelengths of 560 to 590nm.

[BRIEF DESCRIPTION OF THE DRAWINGS]

Fig. 1 is a block diagram showing the construction of an embodiment of an optical communication apparatus according to the present invention.

Fig. 2 is a diagram showing the wavelength-dependence of a transmission loss of a plastic optical fiber.

Fig. 3 is a diagram showing the wavelength-dependence of the transmission loss of the plastic optical fiber before and after a heat-resistance test.

Fig. 4 is a diagram showing the temperature characteristic of transmission level.

[BEST MODES TO IMPLEMENT THE INVENTION]

In an optical communication apparatus of the present invention, an optical transmitter is connected to one end of a plastic optical fiber, and an optical receiver is connected to the other end of the plastic optical fiber. Light emitted from the optical transmitter propagates through the plastic optical fiber to the optical receiver.

In the present invention, a short-wavelength light-emitting element of the optical transmitter is a light-emitting element having the maximum light emission wavelength shorter than that of a red light-emitting element (the maximum light emission wavelength of 640 to 670nm) serving as a light source used in the conventional optical communication apparatus having the plastic optical fiber. As the short-wavelength light-emitting

element may be used a light-emitting element having the maximum light emission wavelength of 600nm or less, such as a yellow light-emitting element having the maximum light emission wavelength of 560 to 590nm or a green light-emitting element having the maximum light emission wavelength of 490 to 550nm. The maximum light emission wavelength of the short-wavelength light-emitting element is set to 400nm or more, for example.

For example, GaN-based or ZnSe-based laser diodes or light emission diodes (LED) may be used as the green light-emitting element, and InGaN-based or InGaAlP-based laser diodes or LEDs may be used as the yellow light-emitting element. Since it is generally difficult at present to achieve a green light-emitting laser diodes and a yellow light-emitting laser diodes, it is preferable to use green light-emitting LED or yellow light-emitting LED. Of these LEDs, GaN-based green light-emitting LED or InGaN-based yellow light-emitting LED is particularly preferable because they have a large light emission amount. Further, in order to reduce the full width at half maximum of wavelength of the short-wavelength light emitting LED, LED having a quantum well structure is preferably used.

In order to achieve long-distance transmission of 150m or more, for example, LED of 40nm or less in full width at half maximum of wavelength and 0dBm or more in total emission light amount is preferably used as the short-wavelength light-emitting element such as the yellow light-emitting element or the like. In order to reduce the full width at half maximum of wavelength of the short-wavelength light-emitting LED such as the yellow light-emitting LED or the like, LED having a single quantum well structure is preferably used.

The optical transmitter may be designed in a well-known structure. For example, it may be constructed by the above short-wavelength light-emitting element, a driving circuit for driving the short-wavelength light-emitting element, a modulation circuit for modulating electrical

signals input from the external and supplying the modulated electrical signals to the driving circuit.

A well-known plastic optical fiber having a core portion through which propagating light mainly passes may be used. For example, a step index type optical fiber having a core/clad structure in which the refractive index varies sharply at the interface between the core and the clad, or a graded index type optical fiber in which the refractive index of the core portion is continuously reduced from the center to the outer periphery thereof may be used. Further, in order to reduce the bending loss, it is preferable to use a multi-core type plastic optical fiber in which plural cores are unified into one body while they are separated from one another through sea form material. In order to broaden the transmission band, it is preferable to use a plastic optical fiber having a core portion formed by coaxially multi-layering (co-)polymer materials which are different in refractive index, the refractive index of the core portion being stepwise reduced from the center to the outer periphery. Such a plastic optical fiber can be achieved by a well-known method, and it can be manufactured by a composite melt spinning method, for example. For example, in order to perform long-distance transmission of 150m or more, it is preferable to use a plastic optical fiber having a transmission loss of 0.1dB/m or less over the light emission wavelength range of the short-wavelength light-emitting element (when a yellow light-emitting element is used as the short-wavelength light-emitting element, the range from 560nm to 590nm in wavelength).

Methacrylate polymer containing no benzene ring is used as the material of the core portion. An optical fiber using methacrylate polymer having no benzene ring as the core material has an excellent transmission characteristic particularly to light emitted from a short-wavelength light-emitting element such as a yellow light-emitting element or a green light-emitting element used in the optical communication apparatus

according to the present invention. A methyl methacrylate polymer is preferably used as the methacrylate polymer. As a methyl methacrylate polymer is preferably used polymer containing methyl methacrylate of 60wt% or more, and more preferably used polymer containing methyl methacrylate of 80wt% or more. Fluorinated alkyl methacrylate is preferably used as monomer to be copolymerized with methyl methacrylate, and 2,2,3,3-tetrafluoropropyl methacrylate is particularly preferably used from the viewpoint of implementation of a low-loss optical fiber. Particularly in the case where an optical fiber having a core portion formed by coaxially multi-layering (co-)polymer materials which are different in refractive index is used, if the respective layers constituting the core portion are formed of the (co-)polymers of methyl methacrylate and 2,2,3,3-tetrafluoropropyl methacrylate which are different in copolymerization composition ratio, it is preferable because the long-distance transmission can be carried out on high-speed signals.

In the manufacturing process of the polymer for the core material, a mercaptan-based chain transfer agent is preferably used to adjust the molecular weight of the polymer for the purpose of adjusting the viscosity of the polymer when it is melted in a process of shaping the polymer into an optical fiber and preventing increase of scattering factors due to structuring in the shaping process. Sulfur components in the chain transfer agent which are bound to the polymer due to a chain transfer reaction enhance neither the light absorption loss when heated nor the scattering loss when humidified, and rather these components enhance the resistance to thermal decomposition of the optical fiber.

The content of sulfur atoms bound to the polymer in the core material is preferably equal to 200ppm or more, and more preferably to 400ppm or more. If the content of sulfur atoms bound to the polymer is excessively small, the resistance to thermal decomposition of the core material is insufficient, or the melting viscosity is excessively increased

so that the shaping of the optical fiber may be difficult. Further, in order to prevent the difficulties of the shaping of the optical fiber due to the excessively reduction in melting viscosity of the core material, the content of sulfur atoms bound to the polymer is preferably set to 1000ppm or less, and more preferably set to 800ppm or less.

As the polymer for the core material is preferably used polymer including a small content of sulfur atoms which are not bound to the polymer, for example, non-reacted mercaptan and disulfide compounds generated through the reaction of mercaptan, etc. (such a content of sulfur is hereinafter merely referred to as "residual sulfur amount"). The content of sulfur atoms which are not bound to the polymer is preferably set to 5ppm or less, and more preferably to 3ppm or less, particularly preferably to 1ppm or less. If a large amount of sulfur atoms which are not bound to the polymer exist in the core material, coloring occurs due to thermal history when the spinning process is carried out, and thus the absorption loss in the wavelength range of 600nm or less, particularly in the wavelength range of 490 to 590nm used mainly in the present invention may be increased. Further, the heat resistance of the optical fiber in the wavelength range is caused to be deteriorated.

Such core material can be achieved as follows. That is, monomers serving as raw material of the core material are partially polymerized to obtain reaction mixture, and then the reaction mixture is degasified under a proper condition by using a vented extruder disclosed in JP(B)-52-17555 for example. In this case, it is preferable that reaction mixture containing polymer of preferably 30 to 70wt% is beforehand heated to increase the temperature thereof to 170℃ or more, the reaction mixture is directly sprayed onto a screw of a supply portion of the vented extruder through a narrow gap such as a pore, slit or the like, most of evaporated materials are separated and withdrawn into a first vent portion kept under a pressure condition of 500Torr or less, and then residual evaporated

materials are removed at a second vent portion disposed at the downstream side of the first vent portion at 200 ℃ to 270 ℃, preferably 230℃ to 270 ℃, and at a pressure of 50Torr or less. Further, a third vent portion under the conditions of 230 ℃ to 270 ℃ and 50Torr or less may be disposed at the downstream side of the second vent portion to remove the evaporated materials. These evaporated materials contain non-reacted monomers, dimers, non-reacted mercaptan, etc.

When a monoaxial vented extruder is used as the vented extruder, the content of sulfur components which are not bound to the polymer is set to 5ppm or less, and thus the supply amount of the reaction mixture and the size of the vent extruder are selected to satisfy the following relationship:

$$Q \leqq 0.002 \times \phi^2 \times \sqrt{(N)}$$

Here, Q: supply amount of reaction mixture [liter/hr]

ϕ: diameter of screw [mm]

N: rotational number of screw [rpm]

When manufacturing polymer for the core, in order to make the degasification easy, it is preferable to use mercaptan having relatively high vapor pressure such as alkylmercaptan having carbon number of 3 to 6 such as n-butylmercaptan, t-butylmercaptan or the like. In order to reduce the use amount of mercaptan, n-butylmercaptan having a large chain transfer constant is particularly preferably used.

Fig. 2 shows a measurement result of the wavelength-dependence of the transmission loss of a plastic optical fiber using methyl methacrylate polymer as core material by using as a parameter the residual amount of sulfur atoms which are not bound to the methyl methacrylate polymer in the core.

Fig. 3 shows measurement results of the wavelength-dependence of the transmission loss before and after a heat resistance test under the conditions of 65℃ and 1000 hours by using the residual sulfur amount as

a parameter. Fig. 3 shows the measurement results for a plastic optical fiber in which the residual sulfur amount in the core is equal to 3.4ppm and a plastic optical fiber in which the residual sulfur amount in the core is equal to 14ppm. The broken lines indicate the measurement results of these plastic optical fibers before the heat resistance test, and solid lines indicate the measurement results after the heat resistance test.

As is apparent from Fig. 2, the residual sulfur amount in the core of the plastic optical fiber has little effect on the transmission loss at the red area of 640 to 670nm in wavelength. On the other hand, in the green area of 490 to 550nm in wavelength and in the yellow area of 560 to 590nm in wavelength, the transmission loss can be remarkably lowered by reducing the residual sulfur amount in the core. Further, as is apparent from Fig. 3, in the red area of 640 to 670nm in wavelength, the residual sulfur amount in the core of the plastic optical fiber has little effect on the heat resistance (the increase in the transmission loss of the plastic optical fiber after the heat resistance test). On the other hand, in the short-wavelength area of 600nm or less in wavelength, the heat resistance can be remarkably enhanced by reducing the residual sulfur amount in the core. That is, when the optical communication apparatus is constructed by using a plastic optical fiber containing methacrylate polymer containing no benzene ring, particularly methyl methacrylate polymer, as the core material, the long-distance transmission can be performed and the heat resistance can be enhanced by using a short-wavelength light-emitting element of a green or yellow light-emitting element as the light-emitting element of the optical transmitter and also using a plastic optical fiber having a small residual sulfur amount in the core.

By using such a combination of the optical transmitter containing the green or yellow short-wavelength light-emitting element and the plastic optical fiber having a small residual sulfur amount in the core as

described above, the coloring of the core in the short-wavelength area due to the thermal oxidation deterioration of sulfur atoms which is not bound to the polymer can be prevented. This is the problem induced when the conventional plastic optical fiber is used. Also the heat resistance can be enhanced. In addition to these effects, an effect that the long-distance transmission can be performed is achieved.

Further, as the methyl methacrylate polymer as the core material is preferably used polymer in which the molecular terminal structure caused by radical initiator has the following chemical formula (1):

$$\begin{array}{ccccc} & CH_3 & & CH_3 & \\ & | & & | & \\ H_3C- & C & -(CH_2- & C & -)_n- \\ & | & & | & \\ & COOCH_3 & & COOCH_3 & \end{array} \quad \cdots\cdots\cdots \ (1)$$

(here, n represents an integer above 1)

This molecular terminal structure is the same as that of methyl methacrylate monomer, and it suffers no effect of light absorption and light scattering due to the heterogeneous molecular structure of the radial initiator, so that such core material is particularly excellent in light-transmitting performance.

SMA type [IEC 60874-2 (Sectional specification for fibre optic connector-TypeF-SMA)] or F07 type [JIS C5976 (F07 type double core optical fiber connector)] is preferably used as a connector to optically connect a short-wavelength light-emitting element such as a yellow light-emitting element or the like to one end face of a plastic optical fiber. Further, for example, in order to perform the long-distance transmission of 150m or more, it is preferable to reduce the connection loss between the short-wavelength light-emitting element such as a yellow light-emitting element or the like and the plastic optical fiber. Such a low connection

loss can be achieved by reducing the light emission area of the short-wavelength light-emitting element such as the yellow light-emitting element or the like or reducing the numerical aperture (NA) of incident light to the optical fiber by using a lens (for example, less than NA of the optical fiber [for example, 0.5]).

A photodetecting diode having sensitivity to the short-wavelength area may be used as the photodetecting element. For example, silicon pin photodiode may be used as the photodetecting diode.

The optical receiver may be designed in a well-known structure. For example, it may be constructed by the above photodetecting element and an amplifying circuit, an identifying circuit, a demodulating circuit, etc. to process the output signal from the photodetecting element and achieve electrical signals to be output to the external.

Like the connector used to optically connect the short-wavelength light-emitting element such as the yellow light-emitting element or the like to one end face of the plastic optical fiber, SMA type or F07 type may be used as a connector to optically connect the other end face of the plastic optical fiber to the photodetecting element.

The optical communication apparatus of the present invention can transmit light through one plastic optical fiber both unidirectionally and bidirectionally. In order to perform the long-distance optical transmission, it is preferable that only light in one way is transmitted through the plastic optical fiber. In a case where the yellow light-emitting element is used as the short-wavelength light-emitting element, if the optical communication apparatus is designed so as to make light transmit only in one way through the plastic optical fiber, the optical communication apparatus thus designed can perform the long-distance optical transmission and has excellent heat resistance, and thus this design is preferable.

The embodiment of the present invention will be described in more

detail with reference to the drawings.

Fig. 1 is a block diagram showing the construction of an embodiment of the optical communication apparatus according to the present invention. In Fig. 1, an optical transmitter 1 and an optical receiver 3 are optically connected to each other through a plastic optical fiber 2. An input electrical signal 11 is input from the external to the optical transmitter 1, and an output electrical signal 35 is output from the optical receiver 3 to the external. The optical coupling between the optical transmitter 1 and one end of the plastic optical fiber 2 is performed by using an SMA connector 4, and the optical coupling between the optical receiver 3 and the other end of the plastic optical fiber 2 is performed by using an SMA connector 5.

The optical transmitter 1 has a modulation circuit 12, a yellow light-emitting diode 14 and a driving circuit 13 for driving the yellow light-emitting diode 14. The modulation circuit 12 subjects the input electrical signal 11 to FSK modulation. For example, when the input electrical signal 11 is equal to 0V, it is converted to a signal of 125kHz, and when the input electrical signal 11 is equal to 5V, it is converted to a signal of 500kHz. The driving circuit 13 drives the yellow light-emitting diode 14, for example, at a high level of 20mA and a low level of 0mA on the basis of the signal from the modulation circuit 12. As the yellow light-emitting diode 14 may be used, for example, an InGaN-based diode having the maximum light emission wavelength of 570nm, the full width at half maximum of wavelength of 38nm and the total emission light amount of 0dBm at a current value of 20mA. The light emission area of the yellow light-emitting diode 14 is set to have a square of 0.2mm in each side length, and NA of incident light to the optical fiber is set to 0.5.

The optical receiver 3 has a silicon pin photodiode 31 having sensitivity to a short-wavelength area such as a yellow area or the like, a photodetection amplifying circuit 32, an identifying circuit 33 and a

demodulating circuit 34. The photodetection amplifying circuit 32 converts the output current of the silicon pin photodiode 31 to the corresponding voltage and then amplifies the voltage. The identifying circuit 33 identifies whether the signal from the photodetection amplifying circuit 32 is high level or low level. The demodulating circuit 34 demodulates the signal from the identifying circuit 33. If the signal is a 125kHz signal, it converts the signal to 0V and outputs it as an output electrical signal 35. If the signal is a 500kHz signal, it converts the signal to 5V and outputs it as an output electrical signal 35. The optical receiver 3 satisfies a bit error rate (BER) of 10^{-7} and an average minimum reception sensitivity of -41.5dBm for NRZ signal of 20kbps at a wavelength of 570nm.

The plastic optical fiber 2 is designed in a step index type so as to have a core formed of polymethyl methacrylate polymer and a clad formed of copolymer of vinylidene fluoride and tetrafluoroethylene. The plastic optical fiber 2 has a residual sulfur amount of 0.7ppm in the core, and the content of sulfur atoms bound to the polymer in the core is equal to 600ppm. The wavelength-dependence of the transmission loss of this plastic optical fiber is shown in Fig. 2.

The measurement of the content of sulfur atoms in the polymer used for the core was carried out as follows.

(i) Measurement of Content of Sulfur Atoms bound to Polymer

The measurement was carried out by using the Dohrman microcoulometric titration apparatus MCTS-130. The measurement was made on standard samples for which the sulfur atom concentration have been known to create a calibration curve. Subsequently, the polymer used for the core was solved in acetone whose amount is ten times as large as the polymer, and the solution was dropped into methanol to precipitate the polymer. Only the polymer was separated and withdrawn, and then dried to obtain a polymer sample. The polymer sample was measured, and the value read on the basis of the calibration curve was converted to a value per

polymer unit amount, and this value was regarded as the amount of sulfur atoms bound to the polymer.

(ii) Measurement of Content of Sulfur Atoms not bound to Polymer

Gas Chromatograph 5890SERIES (II) produced by HP company was used as a measuring apparatus, and TC-WAX produced by GL Sciences Inc. having 30m in length, 0.53mm in inner diameter and 1.0 μm in thickness was used as a column. A flame photometry detector having high sensitivity to sulfur was used as a detector to carry out quantitative analysis of n-butyl mercaptan or n-octyl mercaptan and disulfide compounds generated through the reaction between these mercaptans, which remain in the polymer. The quantitative analysis was carried out as follows. That is, acetone was used as solvent, and standard liquid whose concentration was known was measured in advance to create a calibration curve. Thereafter, sample liquid in which the polymer was solved at a polymer concentration of about 13wt/vol% was measured, a quantitative value obtained from the calibration curve was converted to a value in terms of sulfur atoms, and the value thus obtained was set as the content of sulfur atoms which were not bound to the polymer.

When n-butyl mercaptan was used, the total value of the values in terms of sulfur atoms for n-butyl mercaptan and di-n-butyl-disulfide was regarded as the content of sulfur atoms which were not bonud to the polymer. When n-octyl mercaptan was used, the total value of the values in terms of sulfur atoms for n-octyl mercaptan and di-n-octyl-disulfide was regarded as the content of sulfur atoms which were not bound to the polymer.

The transmission loss measured with collimated light of 570nm in wavelength was equal to 0.06dB/m. The transmission loss when the optical transmitter 1 was connected was increased up to 0.1dB/m because the loss due to the spreading of the wavelength of the light emission diode 14 and increase of loss caused by higher mode components.

The yellow light-emission diode 14 is optically coupled to one end of the plastic optical fiber 2 by the SMA connector 4. The average transmission level of the optical transmitter 1 (the light amount level under the state that the modulation is applied after 1-m transmission through the optical fiber is carried out) is equal to -9dBm.

The silicon pin photodiode 31 is optically coupled to the other end of the plastic optical fiber 2 by the SMA connector 5.

A transmission experiment and a heat resistance test were carried as follows by using an optical communication apparatus as described with reference to Fig. 1 and an optical communication apparatus obtained by partially modifying the former optical communication apparatus.

[Example 1]

The optical communication apparatus shown in Fig. 1 was disposed in a thermostat, and the temperature characteristic at the transmission level was measured. Fig. 4 shows the result thereof. In Fig. 4, the light amount level at a temperature of 25 ℃ is indicated as 0dB. In the optical communication apparatus used, it was confirmed that the transmission level was stable in a broad temperature range of 0 to 85℃ and the heat resistance was excellent.

Next, the transmission loss characteristic of the plastic optical fiber 2 used for the optical communication apparatus at 85℃ under a dry condition was measured with respect to the time. As a result, no increase of the transmission loss at 570nm in wavelength was observed after 1000 hours.

From the above result, it was found that in the optical communication apparatus used in Example 1, both the light-emitting element and the optical fiber had excellent heat resistance, and 300m long-distance transmission could be performed in 20kbps NRZ signal transmission (the bit error rate in the digital signal transmission was equal to or less than 10^{-7}: the same is achieved with respect to the transmissible distance

in the following description).

[Example 2]

The optical communication apparatus was designed in the same construction as Example 1 except that a green light emission diode was used in place of the yellow light emission diode 14.

The green light emission diode used was based on InGaN type, and at the current value of 20mA, the maximum light emission wavelength was equal to 525nm, the full width at half maximum was equal to 20nm, and the total emitted light amount was equal to 3dB. The average transmission level of the optical transmitter 1 was equal to -7dBm. The average minimum photodetecting sensitivity of the optical receiver 3 satisfying BER of 10^{-7} or less in the 20kbps NRZ signal transmission was equal to -41.0dB at the wavelength of 525nm.

Like Example 1, the heat resistance test of the optical communication apparatus was carried out. Fig. 4 shows the result thereof. In the optical communication apparatus used in Example 2, it was found that the transmission level was stable in a broad temperature range from 0 to 85 ℃, and the heat resistance was excellent.

Like Example 1, the transmission loss characteristic of the plastic optical fiber 2 was measured with respect to the time. As a result, no increase of the transmission loss of the optical fiber at the wavelength of 525nm was observed after 1000 hours.

From the above result, it was found that in the optical communication apparatus used in Example 2, both the light emitting element and the plastic optical fiber had excellent heat resistance and 320m long-distance transmission could be performed in 20 kbps NRZ signal transmission.

[Example 3]

The optical communication apparatus was designed in the same construction as Example 1 except for use of a plastic optical fiber 2 in

which the residual sulfur amount in the core was equal to 27ppm and the content of sulfur atoms bound to the polymer was equal to 590ppm (the wavelength-dependence of the transmission loss is shown in Fig. 2).

The transmission loss measured with collimated light at the wavelength of 570nm was equal to 0.09dB/m. The transmission loss when the optical transmitter 1 was connected was increased up to 0.13dB/m because the loss due to the spreading of the wavelength of the yellow light-emitting diode 14 and increase of loss caused by higher mode componemts.

Like Example 1, the transmission loss characteristic of the plastic optical fiber 2 was measured with respect to the time. As a result, an increase of the transmission loss of about 0.005dB/m at the wavelength of 570nm was observed after 1000 hours.

From the above result, the heat resistance characteristic of the optical fiber in the optical communication apparatus used in Example 3 is lower than Example 1, however, the reduction degree is permissible to the actual use of the optical fiber, and thus the heat resistance can be judged as being good. Further, 240m transmission can be performed in the 20kbps NRZ signal transmission, and even if the thermal deterioration at 85℃ in 10,000 hours estimated on the basis of the heat resistance test result is taken into consideration, the transmission distance is equal to 180m.

[Comparative Example 1]

The optical communication apparatus was designed in the same construction as Example 1 except that a red light emission diode was used in place of the yellow light emission diode 14.

The red light emission diode used here was based on GaAlAs type, and at the current value of 20mA, the maximum light emission wavelength was equal to 660nm, the full width at half maximum was equal to 20nm, and the total emitted light amount was equal to 6dBm.

As shown in Fig. 2, the transmission loss of the plastic optical fiber 2 at the wavelength of 660nm was equal to 0.17dB/m. However, when the optical transmitter 1 was connected, the transmission loss became to 0.23dB/m because of spreading of the wavelength of the light emission diode and increase of the loss caused by higher mode components. The average transmission level of the optical transmitter 1 was equal to -6dBm. The average minimum photodetecting sensitivity of the optical receiver 3 satisfying BER of 10^{-7} in the 20kbps NRZ signal transmission was equal to -43.0dB at the wavelength of 660nm.

Like Example 1, the heat resistance test of the optical communication apparatus was carried out with respect to the time. Fig. 4 shows the test result. In the optical communication apparatus used in Comparative Example 1, the transmission level was greatly varied to 2.5dB in the temperature range from 0 to 85 ℃.

Like Example 1, the transmission loss characteristic of the plastic optical fiber 2 was measured with respect to the time. As a result, no increase of the transmission loss of the optical fiber at the wavelength of 660nm was observed after 1000 hours.

From the above result, it was found that in the optical communication apparatus used in Comparative Example 1 the heat resistance characteristic of the light-emitting element was deteriorated and only the transmission of 150m or less can be performed in the 20kbps NRZ signal transmission. Further, when expecting the temperature variation of the transmission level in the range from 0 to 85℃, the transmission distance was expected as 140m.

[Comparative Example 2]

The optical communication apparatus was designed in the same construction as Example 2 except that in the optical fiber 2 being used, the residual sulfur amount in the core was equal to 27ppm, and the content of sulfur atoms bound to the polymer was equal to 590ppm (Fig. 2 shows the

wavelength-dependence of the transmission loss).

At the wavelength of 525nm, the transmission loss measured with collimated light was equal to 0.09dB/m. When the optical transmitter 1 was connected, the transmission loss was increased up to 0.13dB/m due to the spreading of the wavelength of the light emission diode 14 and the increase of the loss caused by the higher mode components.

Like Example 1, the transmission loss characteristic of the plastic optical fiber 2 was measured with respect to the time. As a result, it was found that increase of the transmission loss of about 0.018dB/m at the wavelength of 525nm was observed after 1000 hours.

From the above result, it was found that in the optical communication apparatus used in Comparative Example 3, the heat resistance characteristic of the optical fiber was deteriorated, and 240m transmission can be performed in the 20kbps NRZ signal transmission. However, from the heat resistance test result, it was also found that when expecting the thermal deterioration of 85 ℃ in 10,000 hours, the transmission distance was expected as 100m.

[Comparative Example 3]

The optical communication apparatus was designed in the same construction as Comparative Example 2 except that in the optical fiber 2 being used, the residual sulfur amount in the core was equal to 27ppm, and the content of sulfur atoms bound to the polymer was equal to 590ppm (Fig. 2 shows the wavelength-dependence of the transmission loss).

At the wavelength of 660nm, the transmission loss measured with collimated light was equal to 0.18dB/m. When the optical transmitter 1 was connected, the transmission loss was increased up to 0.24dB/m due to the spreading of the wavelength of the light emission diode 14 and the increase of the loss caused by the higher mode components.

Like Example 1, the transmission loss characteristic of the plastic optical fiber 2 was measured with respect to the time. As a result, no

increase of the transmission loss of the optical fiber at the wavelength of 660nm was observed after 1000 hours.

From the above result, it was found that in the optical communication apparatus used in Comparative Example 3, the heat resistance characteristic of the light-emitting element was deteriorated and only the transmission of 150m or less could be performed. Further, it was found that when expecting the temperature variation of the transmission level in the range from 0 to 85℃, the transmission distance was expected as 140m.

The following table 1 shows the summarized results of Examples 1 to 3 and Comparative Examples 1 to 3.

[TABLE 1]

	EXAMPLE			COMPARATIVE EXAMPLE		
	1	2	3	1	2	3
<u>OPTICAL TRANSMITTER</u>						
LIGHT SOURCE COLOR (WAVELENGTH[nm])	Yellow (570)	Green (525)	Yellow (570)	Red (660)	Green (525)	Red (660)
AVERAGE TRANSMISSION LEVEL	-9	-7	-9	-6	-7	-6
<u>OPTICAL RECEIVER(20kbps)</u>						
MAXIMUM RECEPTION SENSITIVITY [dBm]	Above -9	Above -7	Above -9	Above -6	Above -7	Above -6
MINIMUM RECEPTION SENSITIVITY [dBm]	-41.5	-41.0	-41.5	-43.0	-41.0	-43.0
<u>OPTICAL FIBER</u>						
RESIDUAL SULFUR AMOUNT [ppm]	0.7	0.7	27.0	0.7	27.0	27.0

TRANSMISSION LOSS [dB/m]	0.06	0.07	0.09	0.17	0.09	0.18
TRANSMISSION DISTANCE [m]						
ROOM TEMPERATURE	300	320	240	150	240	150
ESTIMATION AT 85℃ IN 10,000 HOURS	300	320	180	140	100	140
HEAT RESISTANCE						
LIGHT-EMITTING ELEMENT	EXCELLENT	EXCELLENT	EXCELLENT	BAD	EXCELLENT	BAD
OPTICAL FIBER	EXCELLENT	EXCELLENT	GOOD	EXCELLENT	BAD	EXCELLENT

In the table 1, the transmission level is the light amount level under the state that modulation is applied after 1m transmission of the optical fiber, the reception sensitivity is the light amount level at which the bit error rate is equal to 10^{-7} or more, the transmission loss is a measurement value for monochromatic collimated light, and the transmission distance is the maximum transmission distance at which the bit error rate is equal to 10^{-7} or less.

[Example 4]

The optical communication apparatus was designed in the same construction as Example 1 except that a multi-core type plastic optical fiber was used as the plastic optical fiber 2.

The multi-core type plastic optical fiber used here is an optical fiber having island-sea structure in which 37 island portions are unified with a common sea portion while the island portions are separated from one another. Each island portion comprises a core and a clad. The core is formed of methyl methacrylate polymer, and the clad and the sea portion are formed of the copolymer of vinylidene fluoride and tetrafluoroethylene.

In the multi-core type plastic optical fiber, the residual sulfur amount in the core was equal to 0.8ppm, and the content of sulfur atoms bound to the polymer in the core was equal to 600ppm.

At the wavelength of 570nm, the transmission loss measured with collimated light was equal to 0.06dB/m. When the optical transmitter 1 was connected, the transmission loss was increased to 0.1dB/m due to the spreading of the wavelength of the light emission diode 14 and the increase of the loss caused by the higher mode components. The average transmission level of the optical transmitter 1 was equal to -10dBm.

Like Example 1, the transmission loss characteristic of the multi-core type plastic optical fiber used here was measured with respect to the time, and as a result, no increase of the transmission loss of the optical fiber at the wavelength of 570nm was observed after 1000 hours.

From the above result, it was found that in the optical communication apparatus used in Example 4, both the light-emitting element and the optical fiber had excellent heat resistance characteristic and the long-distance transmission of 290m could be performed in the 20kbps NRZ signal transmission.

[Example 5]

The optical communication apparatus was designed in the same construction as Example 1 except that a multi-layered plastic optical fiber was used as the plastic optical fiber 2.

The multi-layered plastic optical fiber used here was designed in a multilayered structure so that the refractive index of the core was stepwise reduced from the center of the core toward the periphery thereof. The inner layer of the core was formed of methyl methacrylate polymer, the outer layer of the core was formed of the copolymer of methyl methacrylate and 2,2,3,3-tetrafluoropropyl methacrylate, and the clad was formed of the polymer of methyl methacrylate and 1,1,2,2-tetrahydroperfluorodecyl methacrylate. The diameter of the inner

layer of the core was equal to 450μm, the thickness of the outer layer of the core was equal to 135 μm, the thickness of the clad was equal to 15μm and the fiber diameter was equal to 750 μm. In the multi-layered plastic optical fiber, the residual sulfur amount in the inner layer of the core was equal to 0.7ppm, and the residual sulfur amount in the outer layer of the core was equal to 1ppm. The content of sulfur atoms bound to the polymer in the inner layer of the core was equal to 600ppm while the content of sulfur atoms bound to the polymer in the outer layer of the core was equal to 560ppm.

At the wavelength of 570nm, the transmission loss measured with the collimated light was equal to 0.06dB/m. When the optical transmitter 1 was connected, the transmission loss was increased to 0.1dB/m due to the spreading of the wavelength of the light emission diode 14 and the increase of the loss caused by the higher mode components. The average transmission level of the optical transmitter 1 was equal to -14dBm.

Like Example 1, the transmission loss characteristic of the multi-layered plastic optical fiber used here was measured with respect to the time, and as a result, no increase of the transmission loss of the optical fiber at the wavelength of 570nm was observed after 1000 hours.

From the above result, it was found that in the optical communication apparatus used in Example 5, both the light emitting element and the optical fiber had excellent heat resistance and the long-distance transmission of 250m could be performed in the 20kbps NRZ signal transmission.

As described above, in the case of the optical communication apparatus using the red light emission diode of the maximum light emission wavelength of 660nm, the transmission distance is short, and the heat resistance of the light emitting element is deteriorated. Even when the residual sulfur amount in the core of the plastic optical fiber is reduced, it has little effect on the transmission distance and the heat resistance.

On the other hand, in the case of the optical communication apparatus using the yellow light emission diode having the maximum light emission wavelength of 570nm and the green light emission diode having the maximum light emission wavelength of 525nm, by reducing the residual sulfur amount in the core of the plastic optical fiber, the transmission distance can be greatly increased and also the heat resistance can be enhanced.

As described above, it has been found that the optical communication apparatus of the present invention is effective to increase the transmission distance and enhance the heat resistance by using the short-wavelength light-emitting element and using the plastic optical fiber including a small residual sulfur amount in the core thereof.

[Industrial Applicability]

As described above, according to the present invention, the optical communication apparatus is constructed by using, in combination, a short-wavelength light-emitting element and a plastic optical fiber having a core formed of methacrylate polymer which is free from benzene ring and has a residual sulfur amount of 5ppm or less, and therefore the long-distance transmission can be performed with excellent heat resistance .

Further, according to the present invention, the optical communication apparatus is constructed by using, in combination, a yellow light emission element and a plastic optical fiber formed of methacrylate polymer free from benzene ring so that the plastic optical fiber makes light transmit in only one direction. Therefore, the heat resistance is enhanced and the long-distance transmission can be performed.

WHAT IS CLAIMED IS

1. An optical communication apparatus, comprising:

an optical transmitter having a short-wavelength light-emitting element for emitting light signals corresponding to electrical signals input from the outside by using light emitted from said short-wavelength light-emitting element;

a plastic optical fiber having a core made of methacrylate polymer free from benzene rings, the amount of sulfur atoms that are not bound to the polymer in said core being set to 5ppm or less, one end of said optical fiber being optically coupled to said short-wavelength light-emitting element; and

an optical receiver having a photodetecting element coupled optically to the other end of said plastic optical fiber and adapted to generate an output electrical signal in accordance with the output of said photodetecting element.

2. The optical communication apparatus as claimed in claim 1, wherein the amount of sulfur atoms that are not bound to the polymer in said core is set to 3ppm or less.

3. The optical communication apparatus as claimed in claim 1, wherein the amount of sulfur atoms that are bound to the polymer in said core is set to a value in the range from 200 to 1000 ppm.

4. The optical communication apparatus as claimed in any one of claims 1 to 3, wherein said short-wavelength light-emitting element emits light having the maximum light emission wavelength of 600nm or less.

5. The optical communication apparatus as claimed in any one of claims 1 to 3, wherein said short-wavelength light-emitting element is a yellow light-emitting diode for emitting light having the maximum light emission wavelength of 560 to 590nm.

6. The optical communication apparatus as claimed in any one of

claims 1 to 3, wherein said short-wavelength light emitting element is a green light-emitting diode for emitting light having the maximum light emission wavelength of 490 to 550nm.

7. An optical communication apparatus, comprising:

an optical transmitter having a yellow light-emitting element for emitting light signals corresponding to electrical signals input from the outside by using light emitted from said yellow light-emitting element;

a plastic optical fiber having a core made of methacrylate polymer free from benzene rings, one end of said optical fiber being optically coupled to said yellow light-emitting element; and

an optical receiver having a photodetecting element coupled optically to the other end of said plastic optical fiber and adapted to generate an output electrical signal in accordance with the output of said photodetecting element, wherein said plastic optical fiber is designed so that light propagates in only one direction.

8. The optical communication apparatus as claimed in claim 7, wherein the amount of sulfur atoms that are not bound to the methacrylate polymer in said core is set to 5ppm or less.

9. The optical communication apparatus as claimed in claim 8, wherein the amount of sulfur atoms that are not bonud to the methacrylate polymer in said core is set to 3ppm or less.

10. The optical communication apparatus as claimed in claim 7, wherein said yellow light-emitting element comprises a light emission diode which has the maximum light emission wavelength in the range from 560nm to 590nm, the full width at half maximum of wavelength of 40nm or less and the total emission light amount of 0dBm or more.

11. The optical communication apparatus as claimed in any one of claims 7 to 10, wherein said plastic optical fiber has a transmission loss of 0.1dB/m or less at the wavelengths of 560 to 590nm, and the connection loss between said yellow light-emitting element and said plastic optical

fiber is equal to 10dB or less.

12. The optical communication apparatus as claimed in any one of claims 7 to 10, wherein said optical receiver has the minimum reception sensitivity of -25dBm or less at the wavelengths of 560 to 590nm.

ABSTRACT OF THE DISCLOSURE

An optical communication apparatus comprises an optical transmitter (1) which emits light signals corresponding to external electric signals (11) using light emitted from a short-wavelength light-emitting element (14) such as a yellow light-emitting diode of maximum wavelength in a range of 560-590 nm or a green light-emitting diode of maximum wavelength in a range of 490-550 nm; a plastic fiber (2) including a methacrylate polymer core free from benzene rings and having one end connected optically with the short-wavelength light-emitting element (14), the core containing less than 5ppm free sulfur; and an optical receiver (3) having a photodetector element (31) connected optically with the other end of the plastic fiber (2) and adapted to producing an output electric signal (35) in accordance with the output from the photodetector element (31).

09/868994

FIG.1

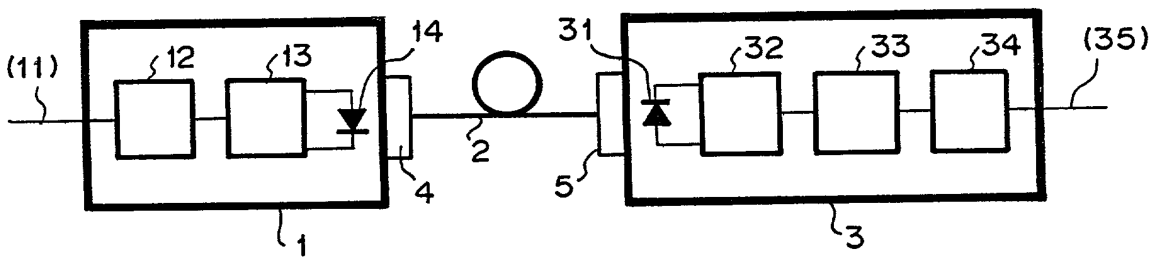
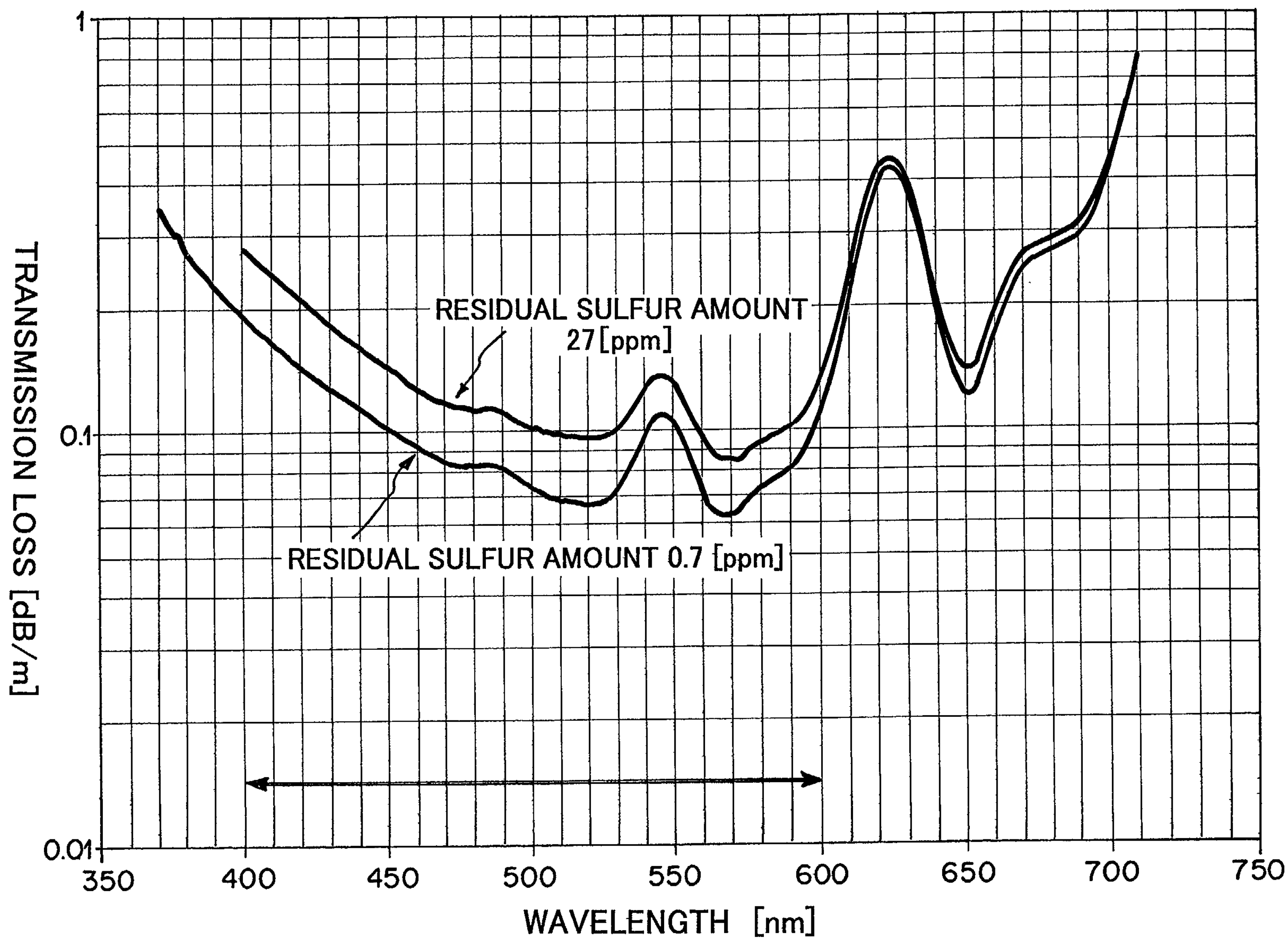


FIG.2



1
0.1
0.01
350
400
450
500
550
600
650
700
750
WAVELENGTH [nm]
TRANSMISSION LOSS [dB/m]
RESIDUAL SULFUR AMOUNT 27 [ppm]
RESIDUAL SULFUR AMOUNT 0.7 [ppm]

09/868994

FIG.3

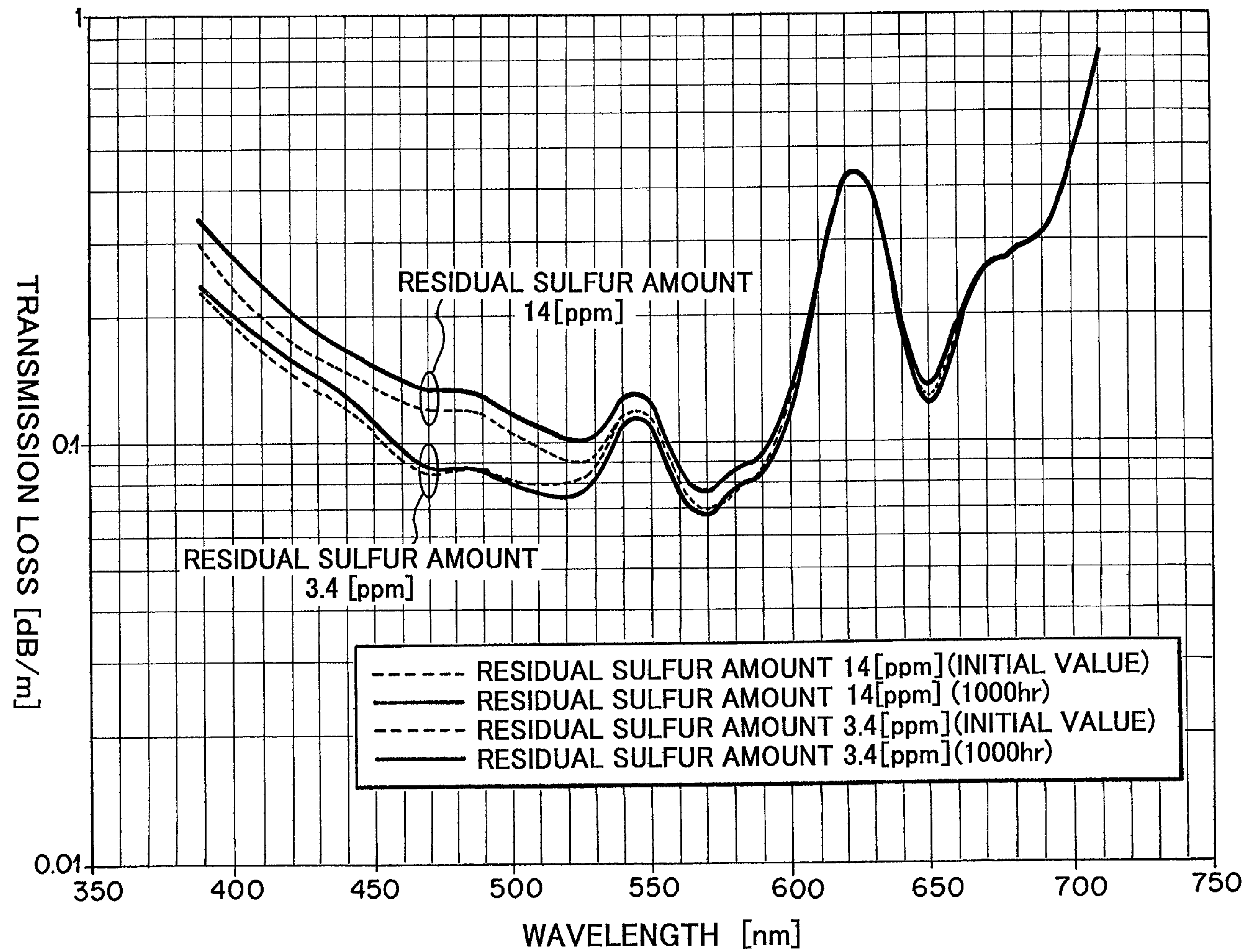
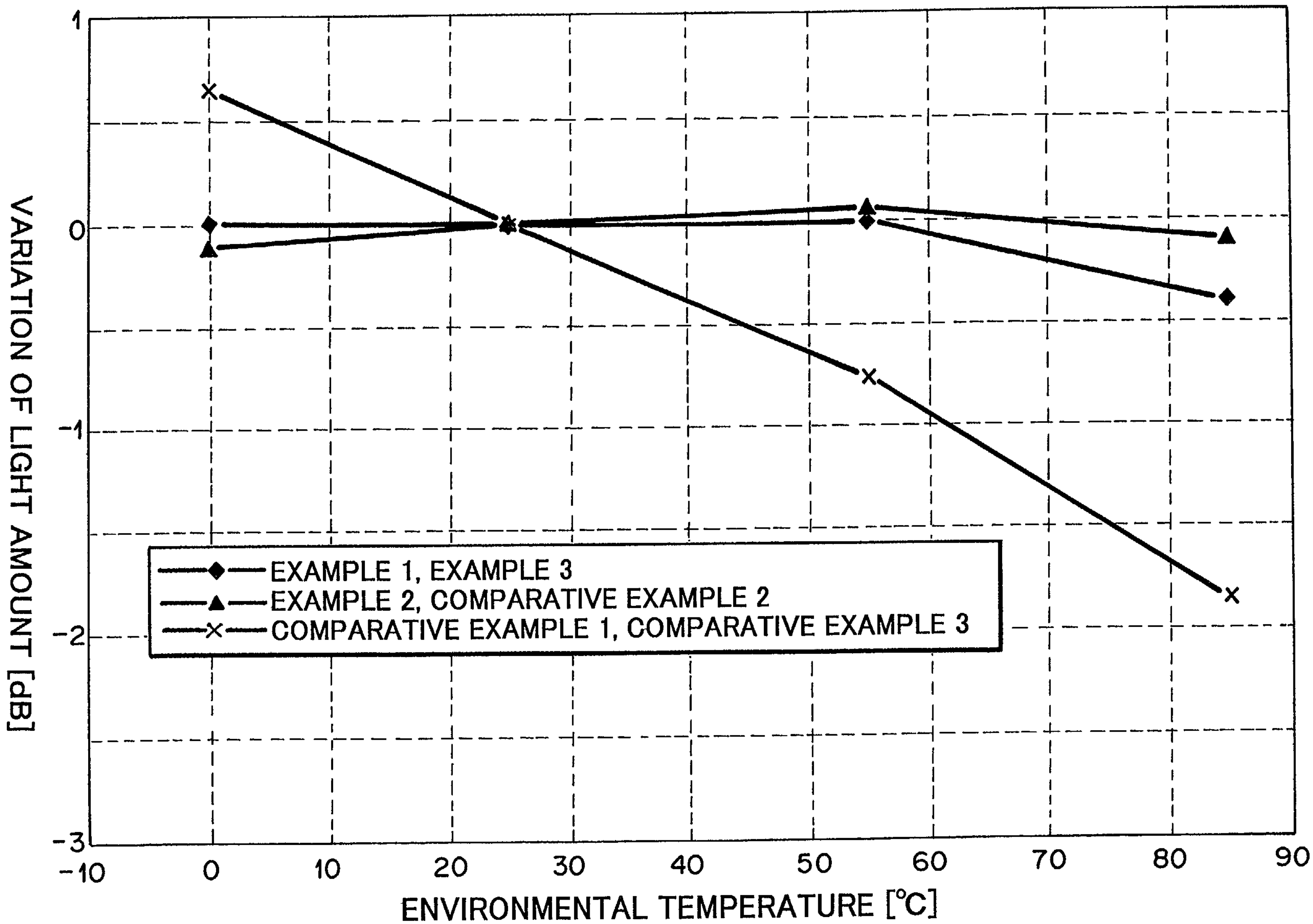


FIG.4



VARIATION OF LIGHT AMOUNT [dB]
1
0
-1
-2
-3
-10
0
10
20
30
40
50
60
70
80
90
ENVIRONMENTAL TEMPERATURE [°C]
EXAMPLE 1, EXAMPLE 3
EXAMPLE 2, COMPARATIVE EXAMPLE 2
COMPARATIVE EXAMPLE 1, COMPARATIVE EXAMPLE 3

Supplemental Data Priority Sheet

☒ Additional foreign application numbers:

Prior Foreign Application Number(s)	Foreign Country	Priority Filing Date	Not Claimed	Certified Copy Attached Yes	No
11-197851	Japan	12/07/1999	☐	☐	☒
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐

☐ Additional provisional application numbers:

Provisional Application Number(s)	Provisional Application Filing Date

☐ Additional U.S. or PCT international application numbers:

Prior U.S. Application Number	Prior PCT International Application Number	U.S. or PCT International Application	Filing Date of Patent Number (if applicable)

Atty. Dkt. No.

FOR UTILITY/DESIGN
CIP/PCT NATIONAL/PLANT
ORIGINAL/SUBSTITUTE/SUPPLEMENTAL
DECLARATIONS

RULE 63 (37 C.F.R. 1.63)
DECLARATION AND POWER OF ATTORNEY
FOR PATENT APPLICATION
IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

As a below named inventor, I hereby declare that my residence, post office address and citizenship are as stated below next to my name, and I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the **invention entitled:**

OPTICAL COMMUNICATION APPARATUS

(Title of Invention)

the specification of which (check applicable box(es):

A. ☒ is attached hereto.

B. ☐ was filed on ____________ as U.S. Application No. ____________

C. ☒ was filed as PCT International Application Number PCT/JP99/07177 on December 21, 1999

and (if applicable to U.S. or PCT application) was amended on ____________

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment specifically referred to above. I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56. I hereby claim foreign priority benefits under Title 35, United States Code, §119(a)-(d) or §365(b) of any foreign application(s) for patent or inventor's certificate, or §365(a) of any PCT international application which designated at least one country other than the United States of America, listed below, and I have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or any PCT international application, on this invention filed by me or my legal representatives or assigns and having a filing date before that of the application on which priority is claimed:

PRIOR FOREIGN APPLICATION(S)

Number(s)	Country	Day/MONTH/Year Filed	Date first Laid-open or Published	Date Patented or Granted	Priority NOT Claimed
10-367308	Japan	24/12/1998			

If more prior foreign applications, X box at bottom and continue on attached page.

Except as noted below, I hereby claim domestic priority benefit under 35 U.S.C. 119(e) or 120 and/or 365(c) of the indicated United States applications listed below and PCT international applications listed above or below and, if this is a continuation-in-part (CIP) application, insofar as the subject matter disclosed and claimed inthis application is in addition to that disclosed in such prior applications, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in 37 C.F.R. 1.56 which became available between the filing date of each such prior application and the national or PCT international filing date of this application:

PRIOR U.S. PROVISIONAL, NONPROVISIONAL AND/OR PCT APPLICATION(S)

Appln. No. (series code/serial no.)	Day/MONTH/Year Filed	Status pending, abandoned, patented	Priority NOT Claimed

As a named inventor, I hereby appoint the practitioners associated with Customer Number 22242, with full power of substitution and revocation, to prosecute this application and to transact all business in the United States Patent and Trademark Office connected therewith, and request that all correspondence and telephone calls in respect to this application be directed to FITCH, EVEN, TABIN & FLANNERY, Suite 1600, 120 South LaSalle Street, Chicago, Illinois 60603-3406, Telephone No. (312) 577-7000, Facsimile No. (312) 577-7007, CUSTOMER NUMBER 22242.

22242

I hereby declare that all statements made herein of my own knowledge are true, and that all statements made herein on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity or enforceability of the application or any patent issued thereon.

☐ Additional inventors, see attached pages.

☒ Additional foreign prior art on attached page (incorporated herein by reference)

(1) Full name of sole or one joint inventor: Tomonari Yoshimura
(Given names first, with Family name last)

Inventor's signature: Tomonari Yoshimura

Date: June 18, 2001

Residence: Aichi, Japan
(City and State for U.S. Residents; City and Country for others)

Mailing Address: c/o Toyohashi Plants, Mitsubishi Rayon Co., Ltd., 1-2, Ushikawadori 4-chome, Toyohashi-shi, Aichi, Japan

Citizenship: Japanese

(2) Full name of sole or one joint inventor: Noritaka Saito
(Given names first, with Family name last)

Inventor's signature: Noritaka Saito

Date: June 18, 2001

Residence: Aichi, Japan
(City and State for U.S. Residents; City and Country for others)

Mailing Address: c/o Toyohashi Plants, Mitsubishi Rayon Co., Ltd., 1-2, Ushikawadori 4-chome, Toyohashi-shi, Aichi, Japan

Citizenship: Japanese

(3) Full name of sole or one joint inventor: Akimitsu Okita
(Given names first, with Family name last)

Inventor's signature: Akimitsu Okita

Date: June 18, 2001

Residence: Aichi, Japan
(City and State for U.S. Residents; City and Country for others)

Mailing Address: c/o Toyohashi Plants, Mitsubishi Rayon Co., Ltd., 1-2, Ushikawadori 4-chome, Toyohashi-shi, Aichi, Japan

Citizenship: Japanese

(4) Full name of sole or one joint inventor:
(Given names first, with Family name last)

Inventor's signature:

Date:

Residence:
(City and State for U.S. Residents; City and Country for others)

Mailing Address:

Citizenship: